Interference Situations in Gamma Spectrometry

2nd Advanced Training Course on Illicit Trafficking and Radiological Consequences with NUCLEONICA

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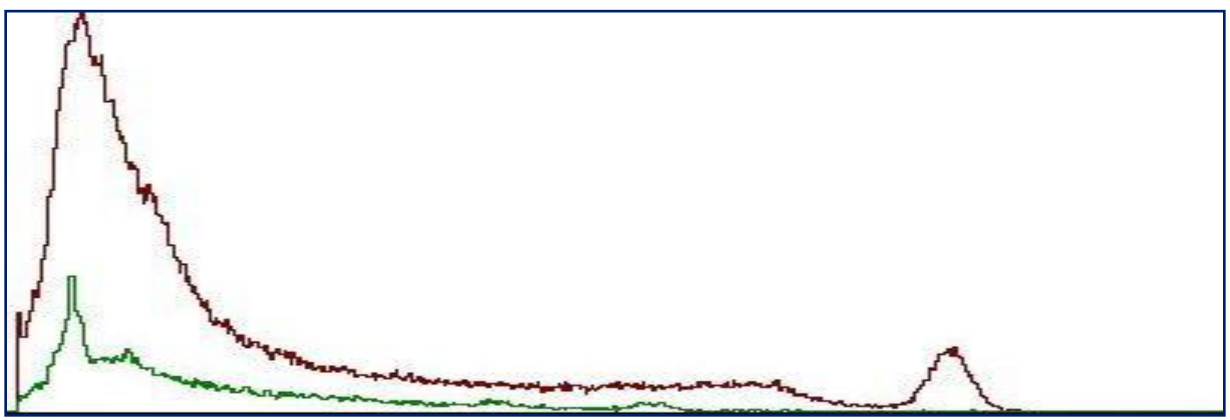
Prevention of nuclear smuggling (Illicit Trafficking)
Nuclide Identification of highest importance

Gamma Spectrometry using
an RID (Radionuclide Identification Device)

Nuclide Identification more difficult, when:
- source shielded
- spectra of two or more sources interfere
  - = **Masking**

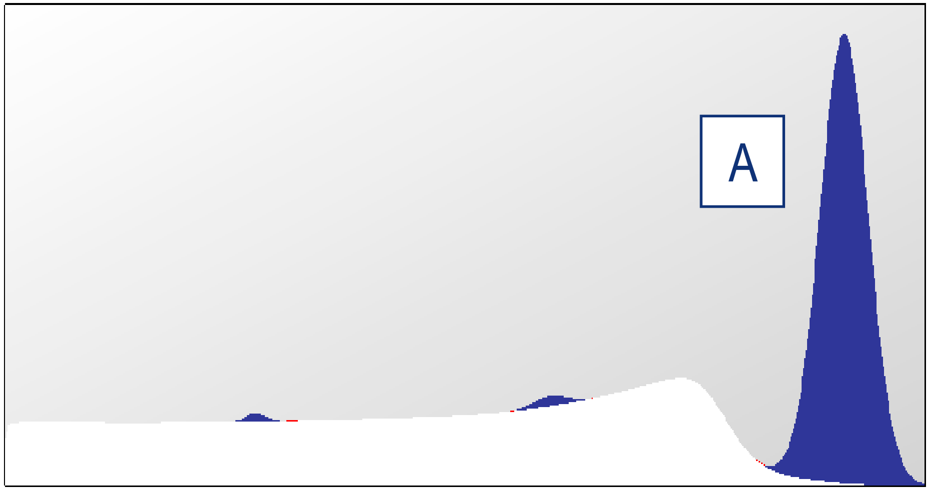


Interaction of gamma rays with matter in the detector volume

transfer of photon energy to electron energy

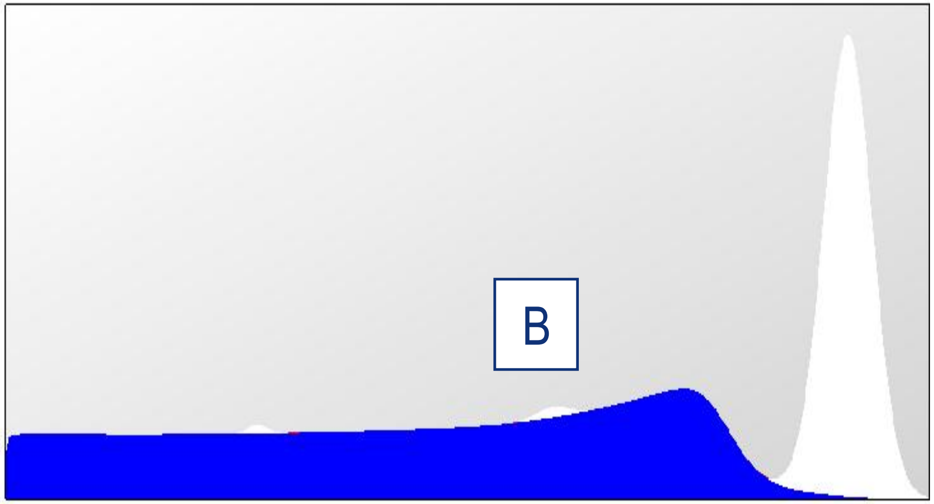
A. **photoelectric absorption** -> photopeak

gamma photon disappears in absorber atom
photoelectron emitted
+ characteristic x-ray or auger electron



B. **Compton scattering** -> continuum

gamma photon scattered – some energy given to an electron, depending on angle
all angles up to max. 180° (Compton edge)
scattered photon escapes detection



C. pair production

gamma energy >> $2m_0c^2$
production of positron + electron

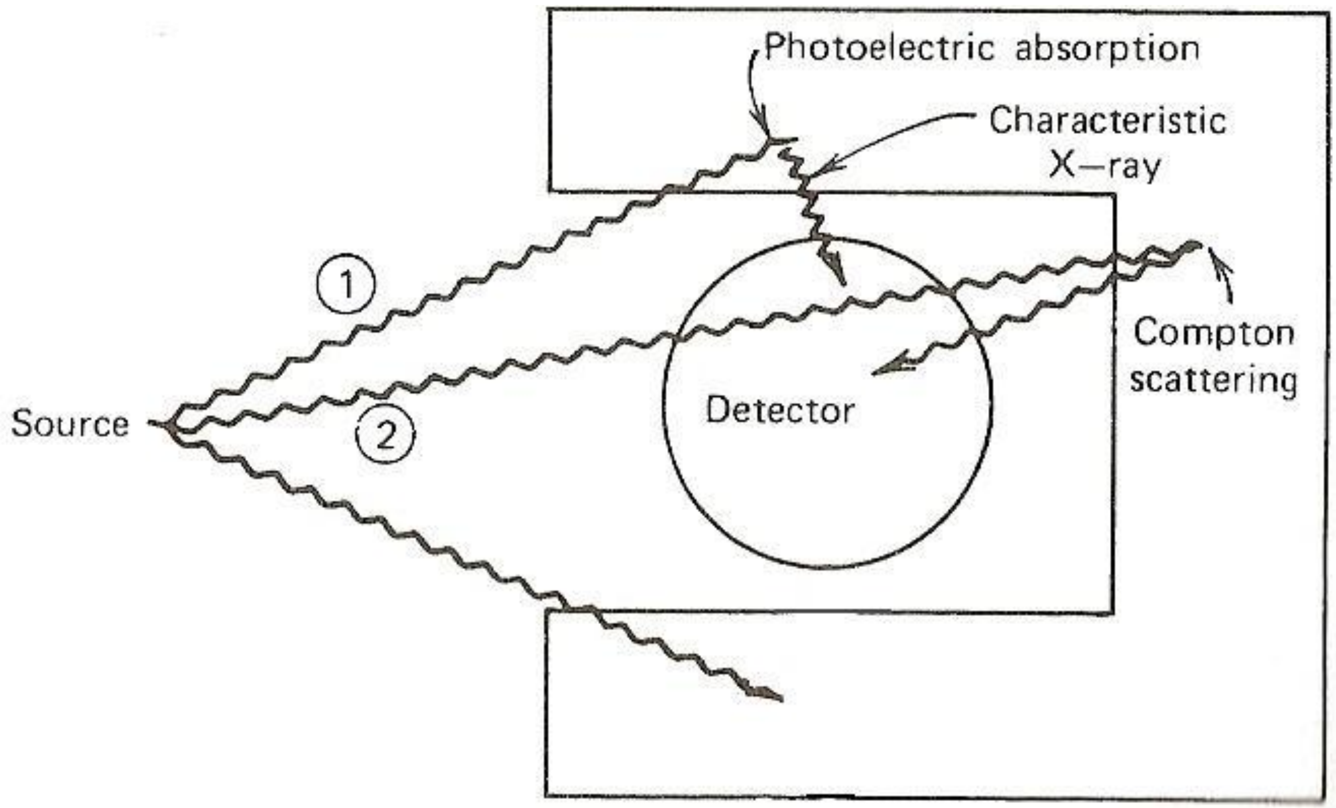
Complicating Effects

selected effects that complicate the detector response function

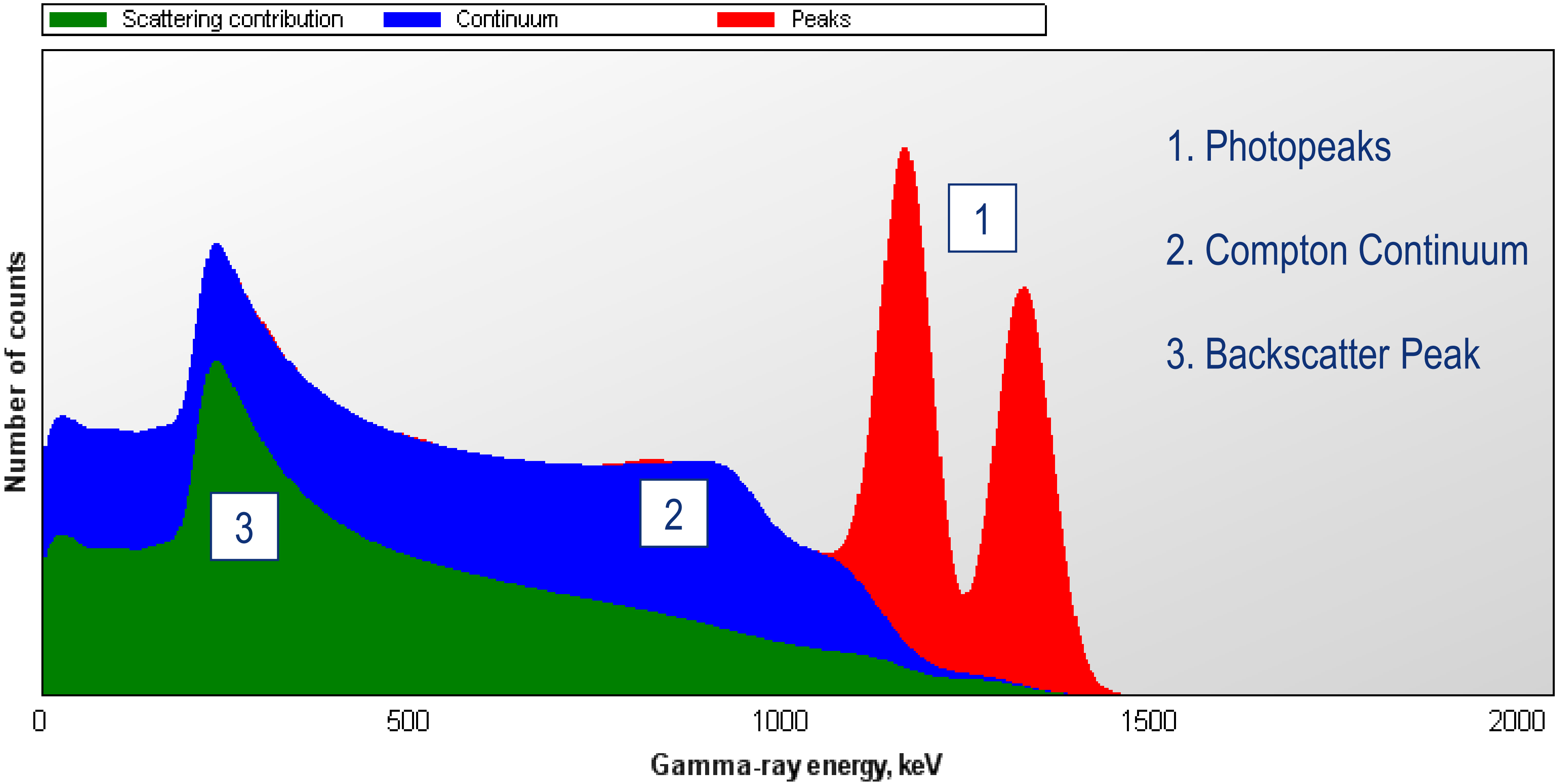
peak-like distortions from the detector surroundings:

1. characteristic x-rays

2. **backscattering**



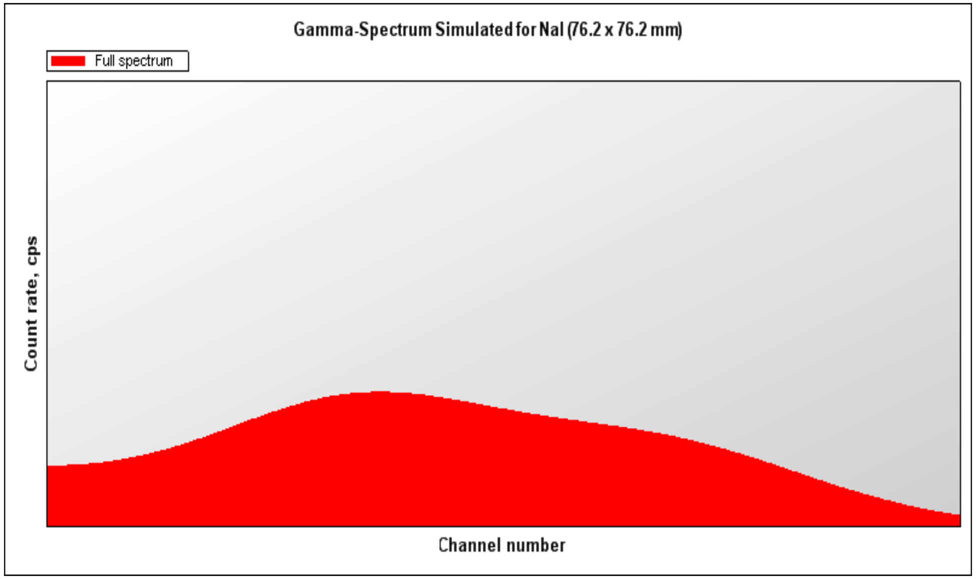
Areas of Interest

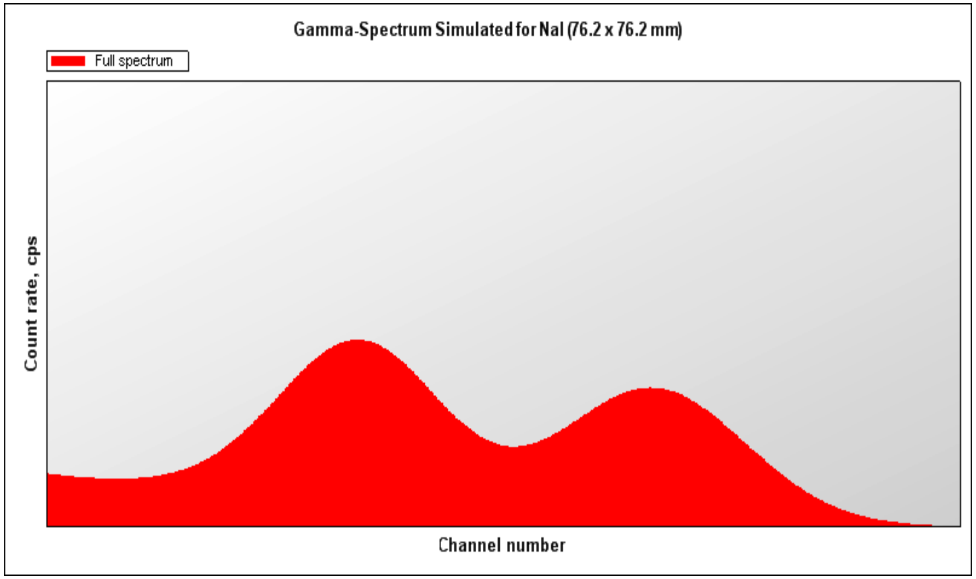


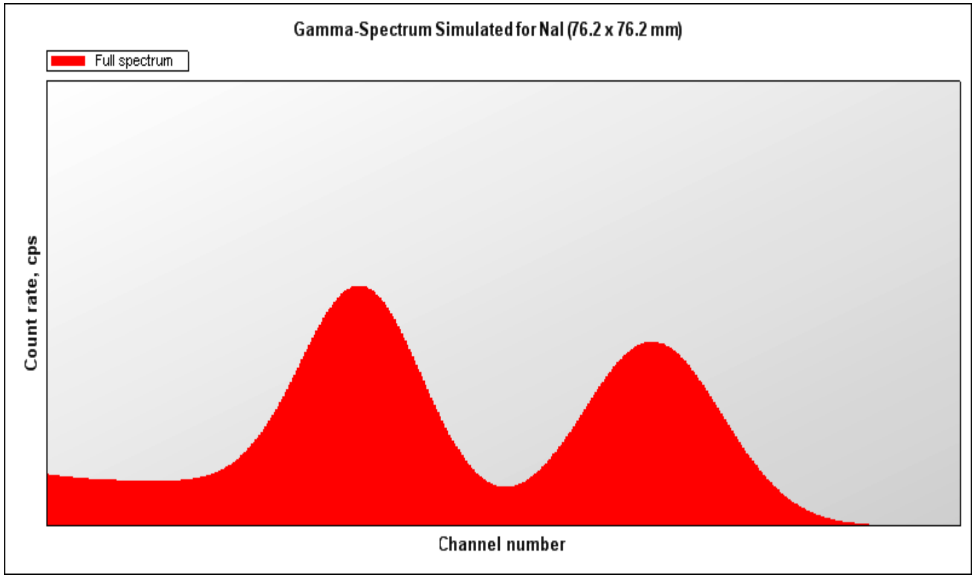
1. Photopeaks
2. Compton Continuum
3. Backscatter Peak

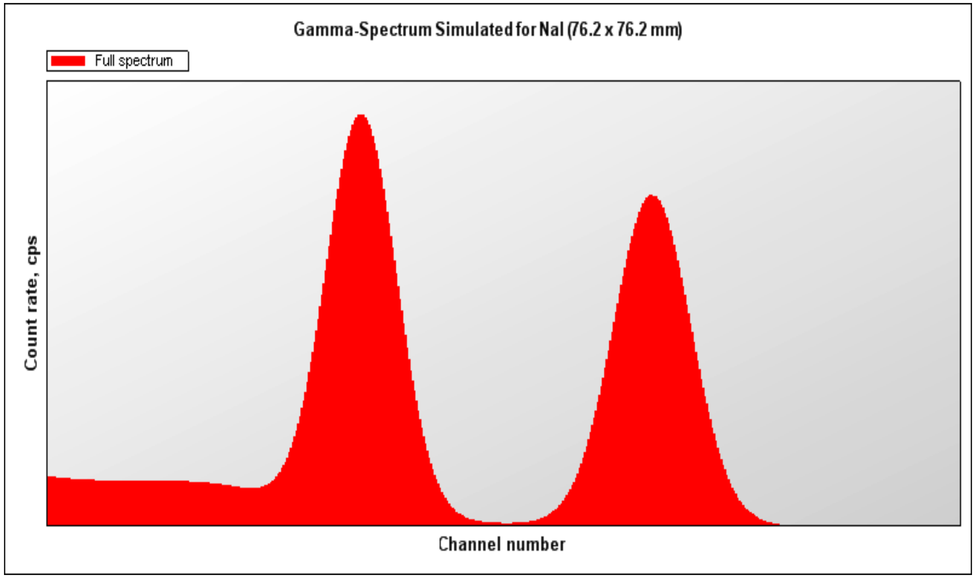
three regions of possible interferences -> three types of Masking

Resolution of Photopeaks

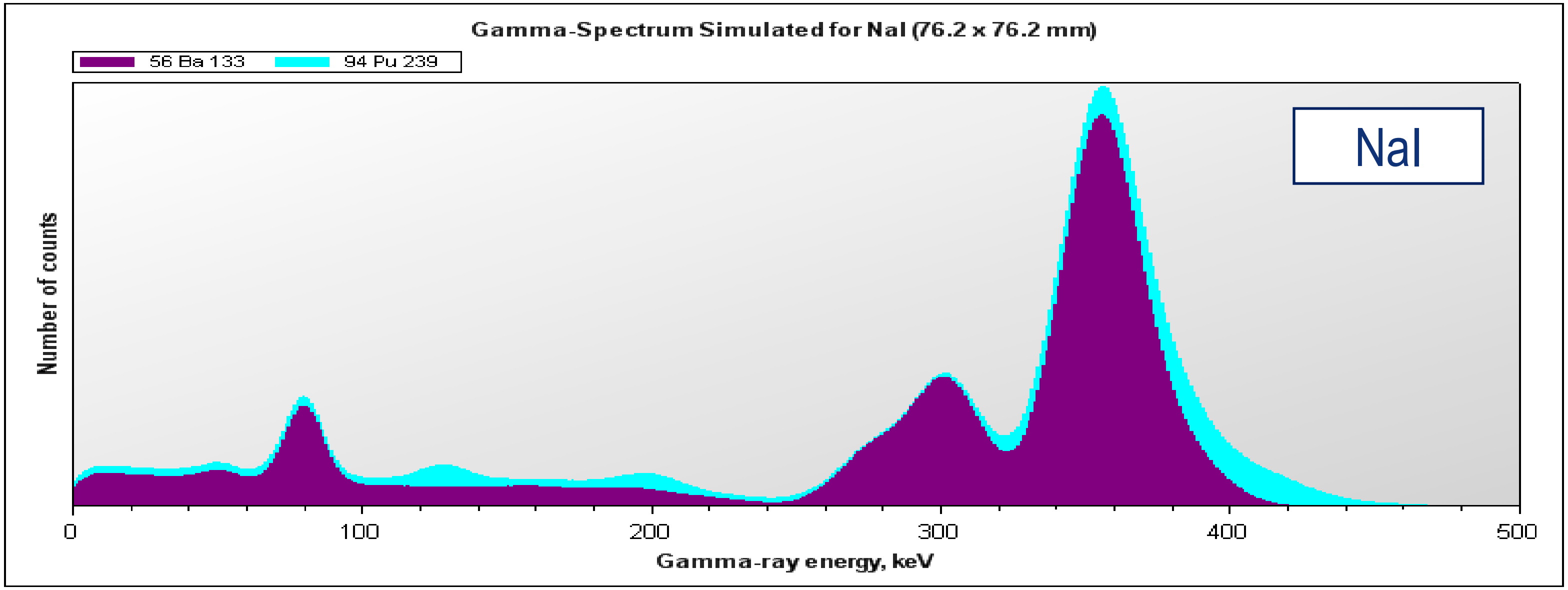


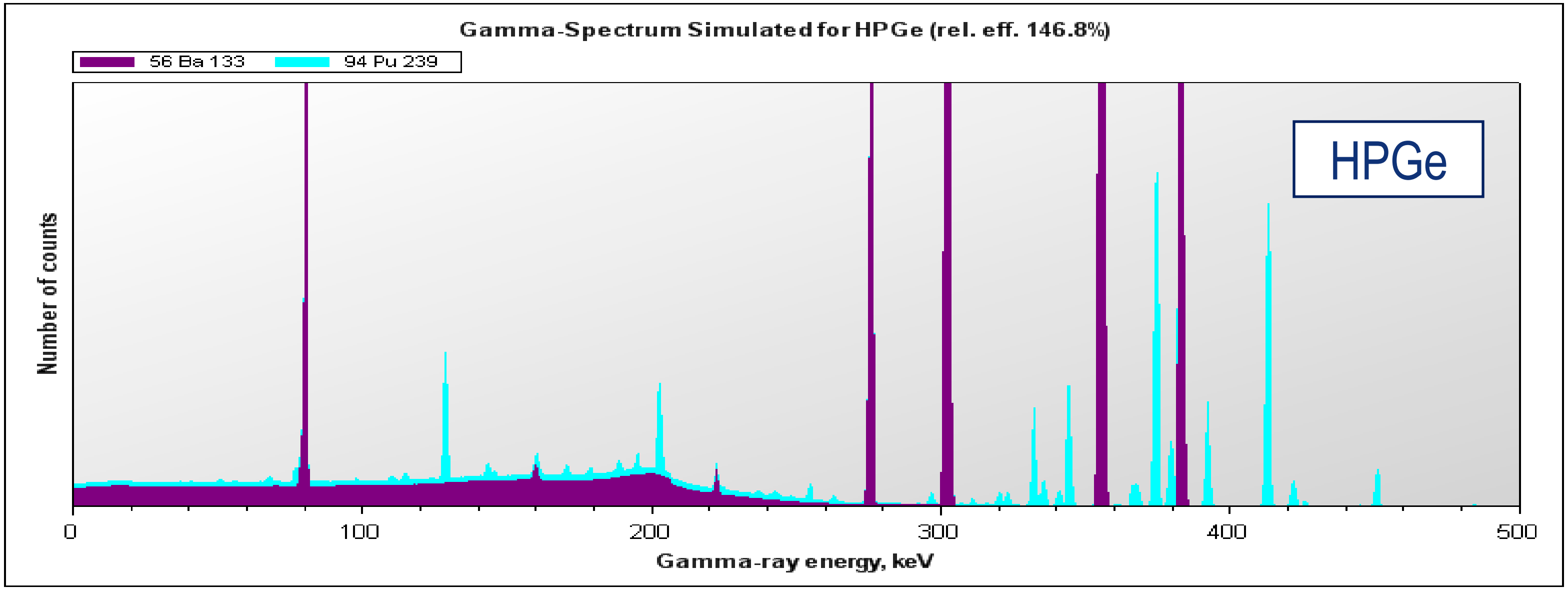






Ba 133 and Pu 239



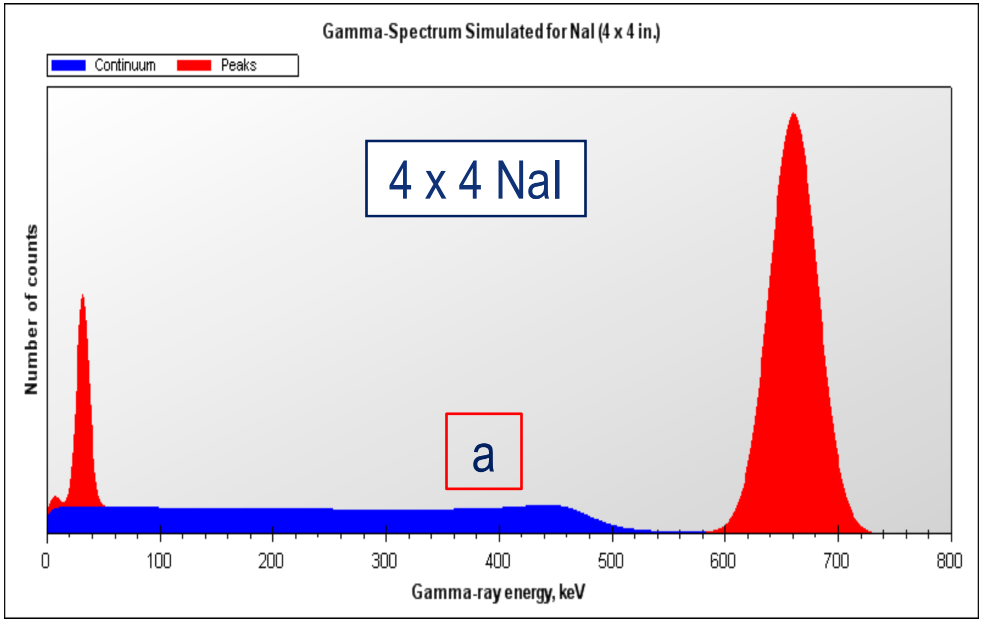


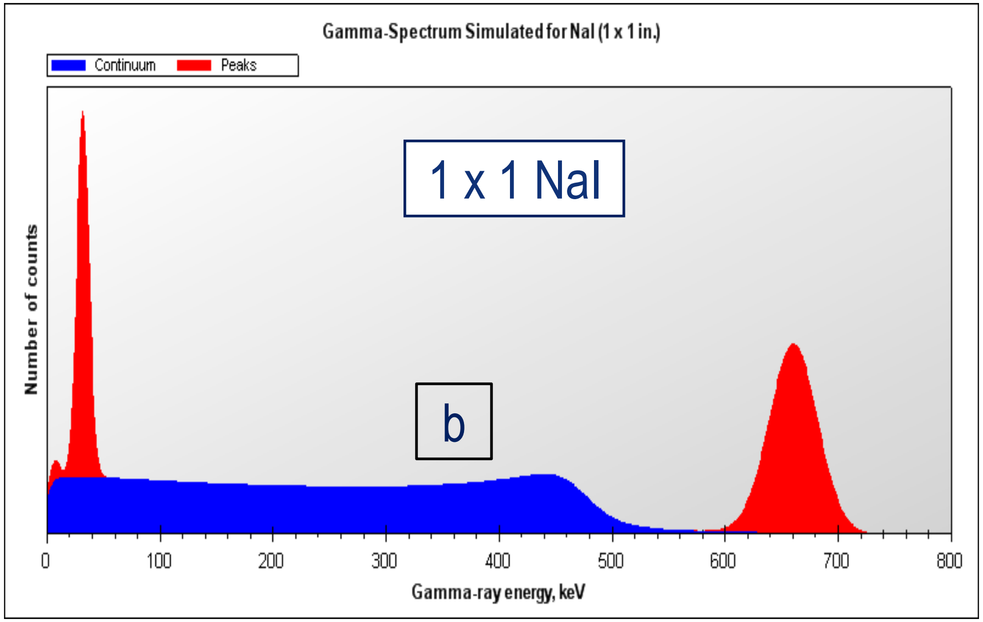
Ba 133 + Pu 239

1mm lead

interferences at adjacent lines

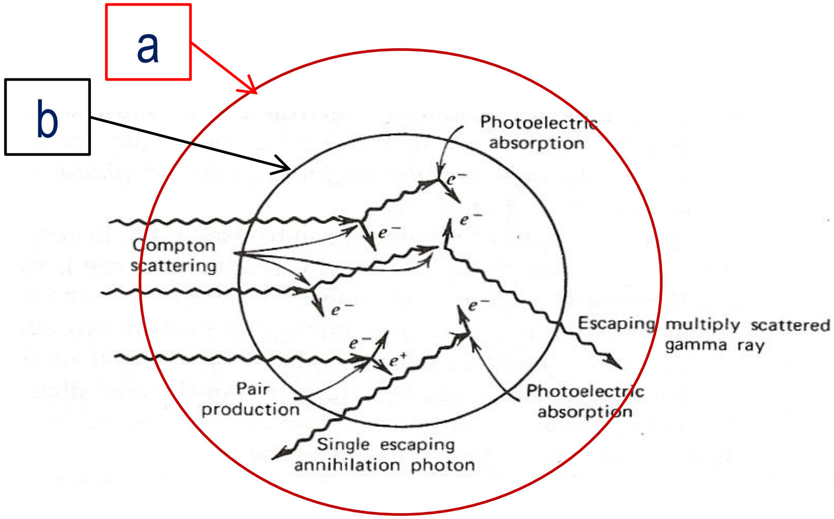
The Continuum



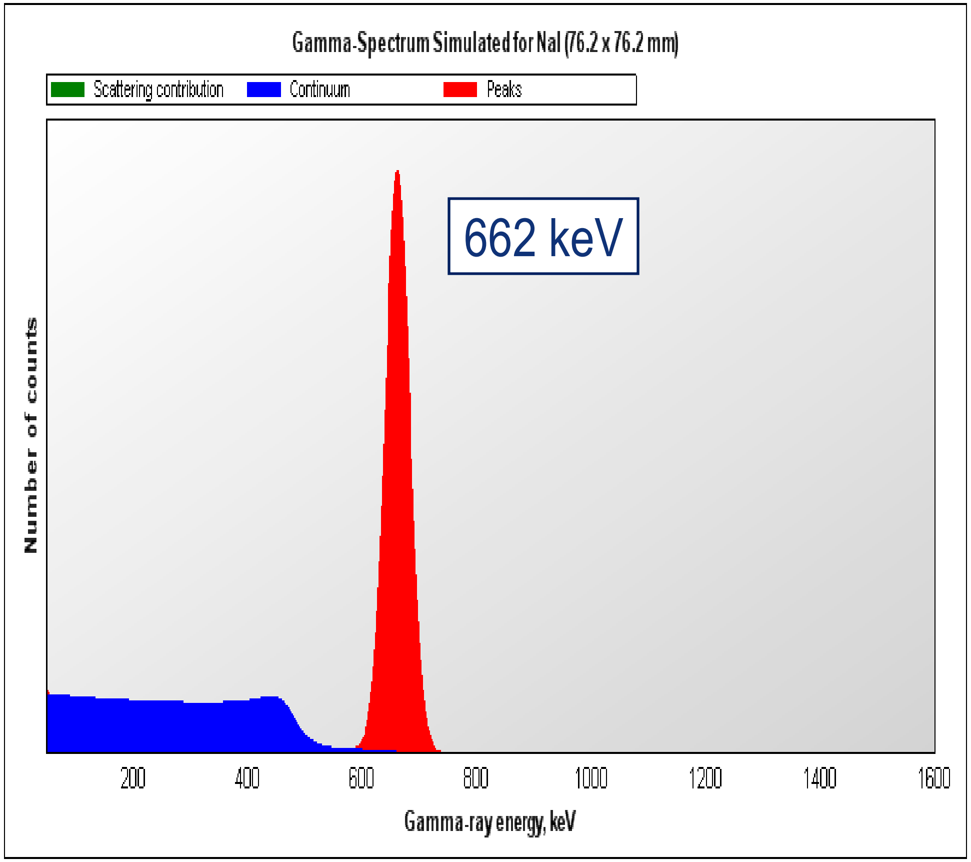


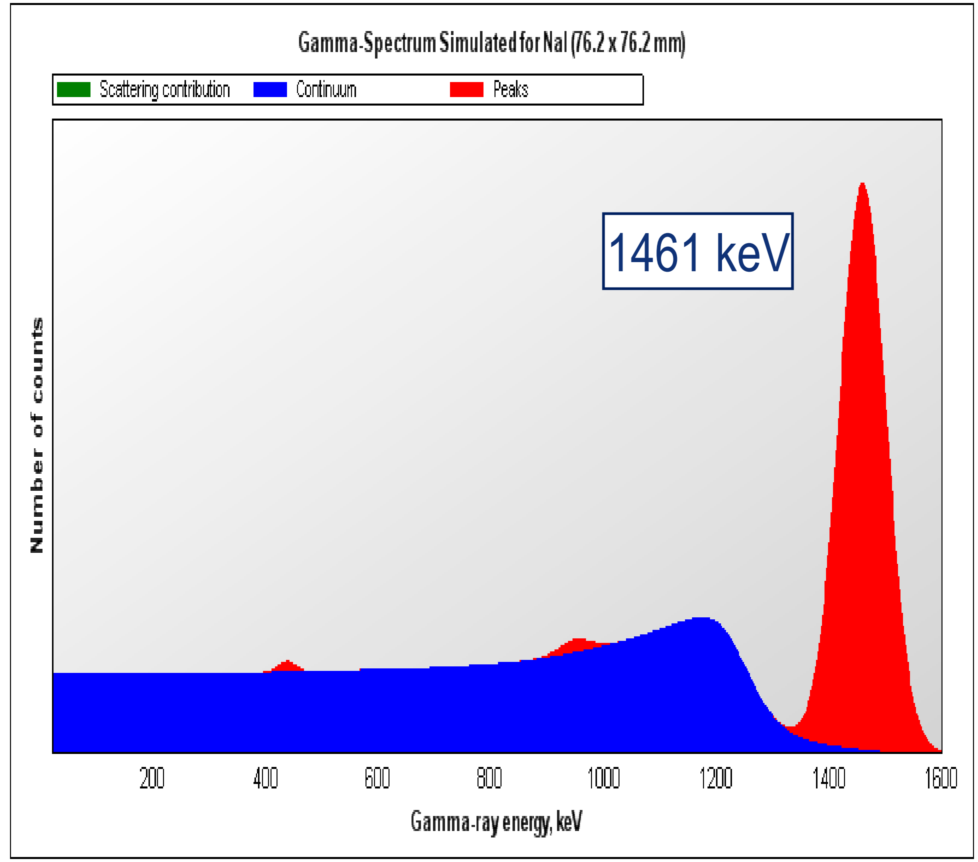
Compton scattering within detector volume
at different angles -> continuum

comparison of different detector volumes shows
different peak – continuum ratio due to escaping particles



The Continuum

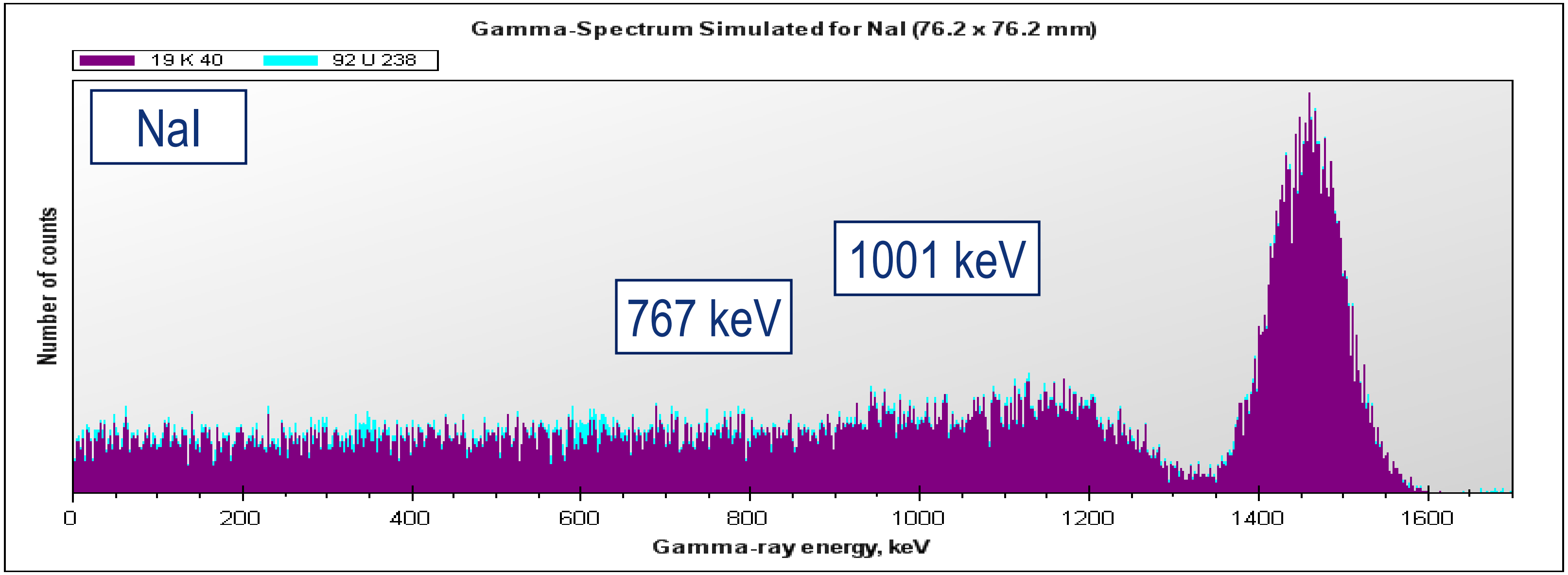




higher initial photon energy -> lower efficiency in full energy peak

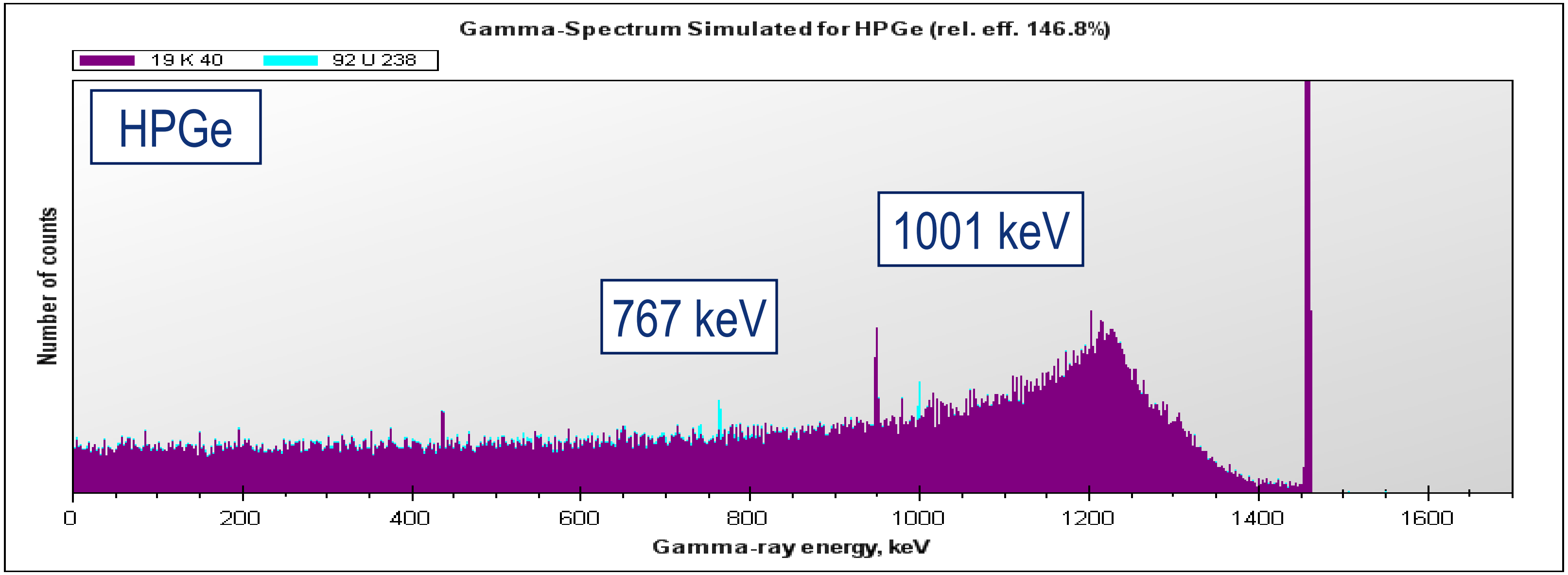
more scattering events and escapes possible -> increased continuum in relation to peak

Fertilizer (K 40) and LEU



K 40 + U 238

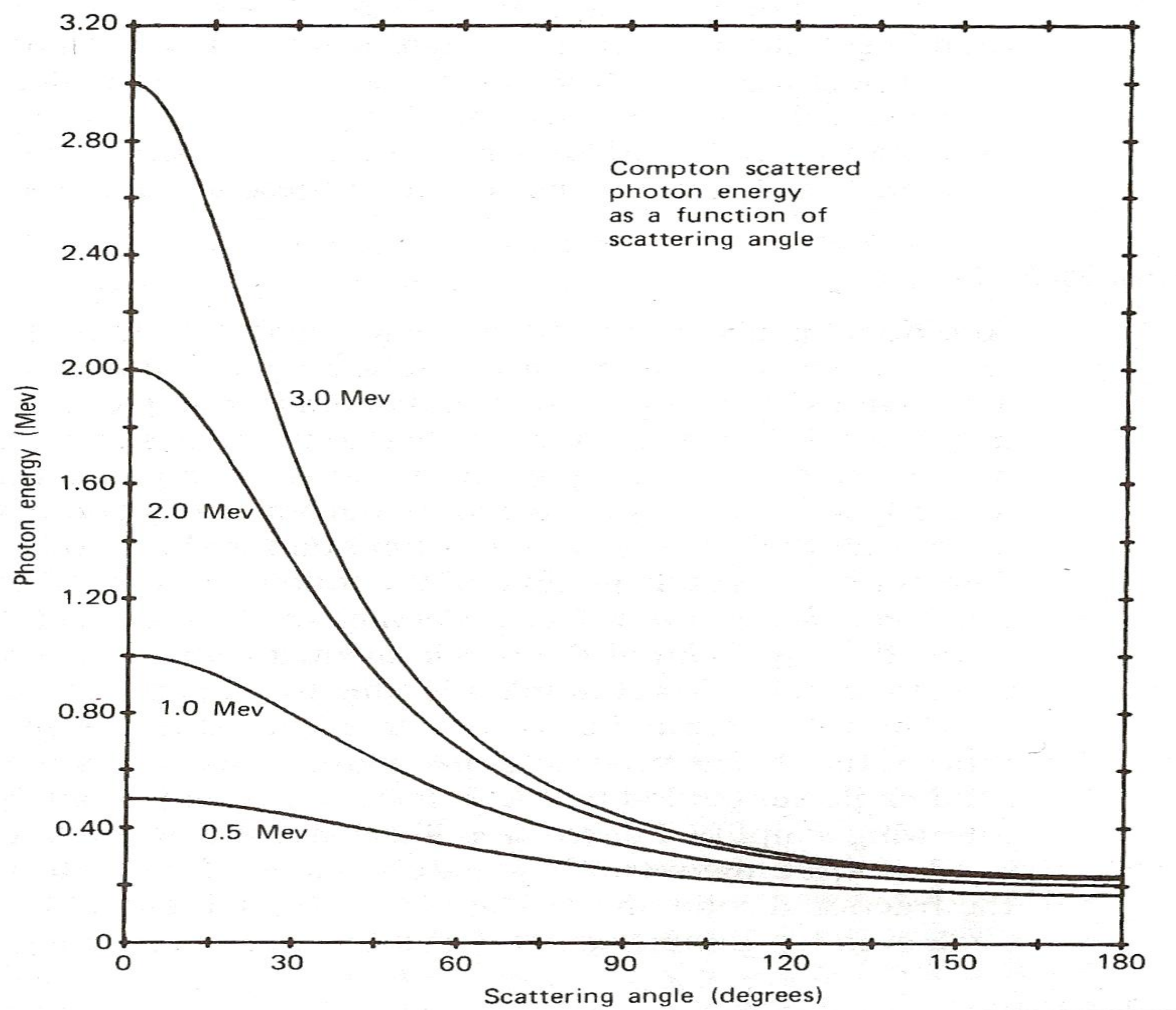
5 mm lead



if statistical fluctuation high compared to peak height of second nuclide, peaks could disappear in continuum

The Backscatter Peak

Compton scattering in the detector surroundings



gamma photon Compton scattered in surrounding material

some energy deposited in electron there

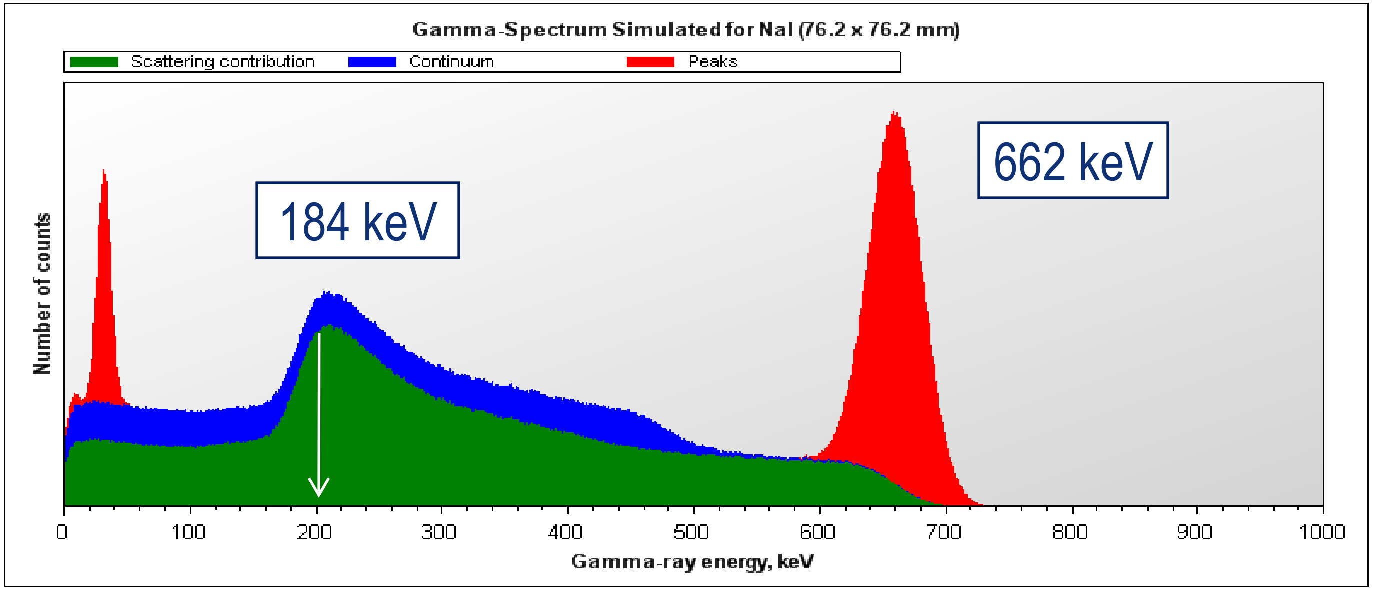
gamma photon with reduced energy scattered back into detector volume

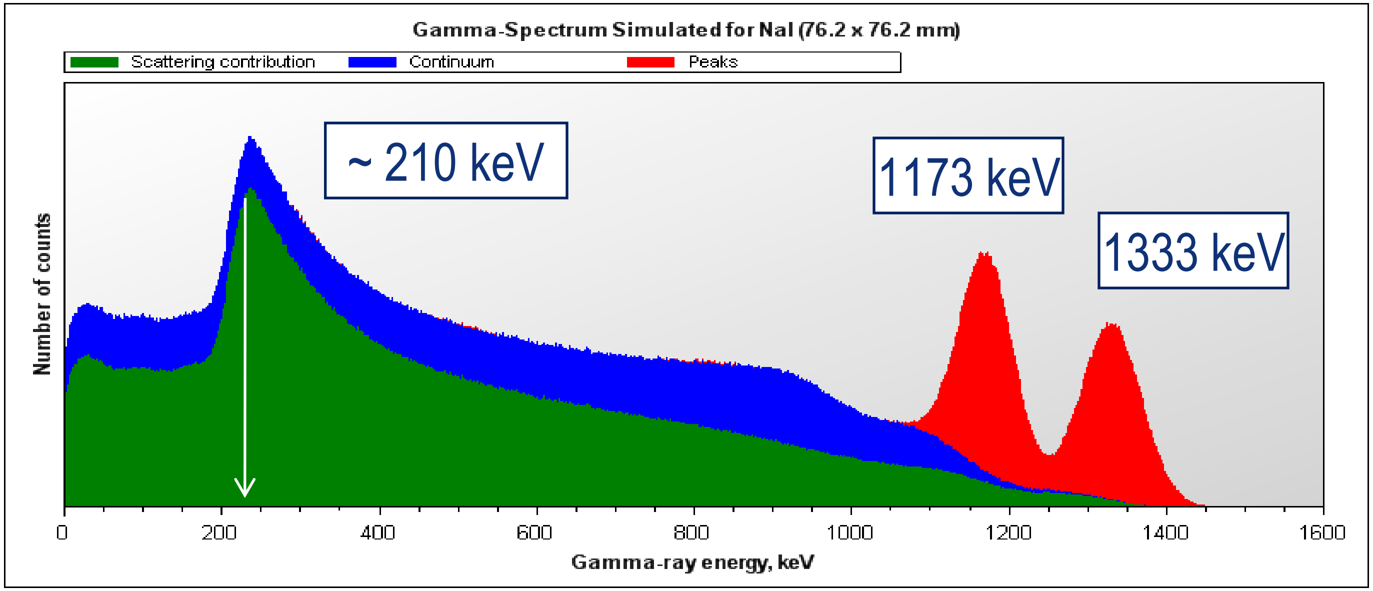
new energy usually ~ 200 keV

for angles greater than 120° independent on original energy

-> backscatter peak

The Backscatter Peak





$$E' = E / (1 + E/m_oc^2 (1 - \cos ß))$$

E'_{back} for backscattering

$ß = 180°$

$m_oc^2 = 511$ keV

$$E'_{back} = E / (1 + 2E/511)$$

$E'_{back\_cesium} = 184$ keV

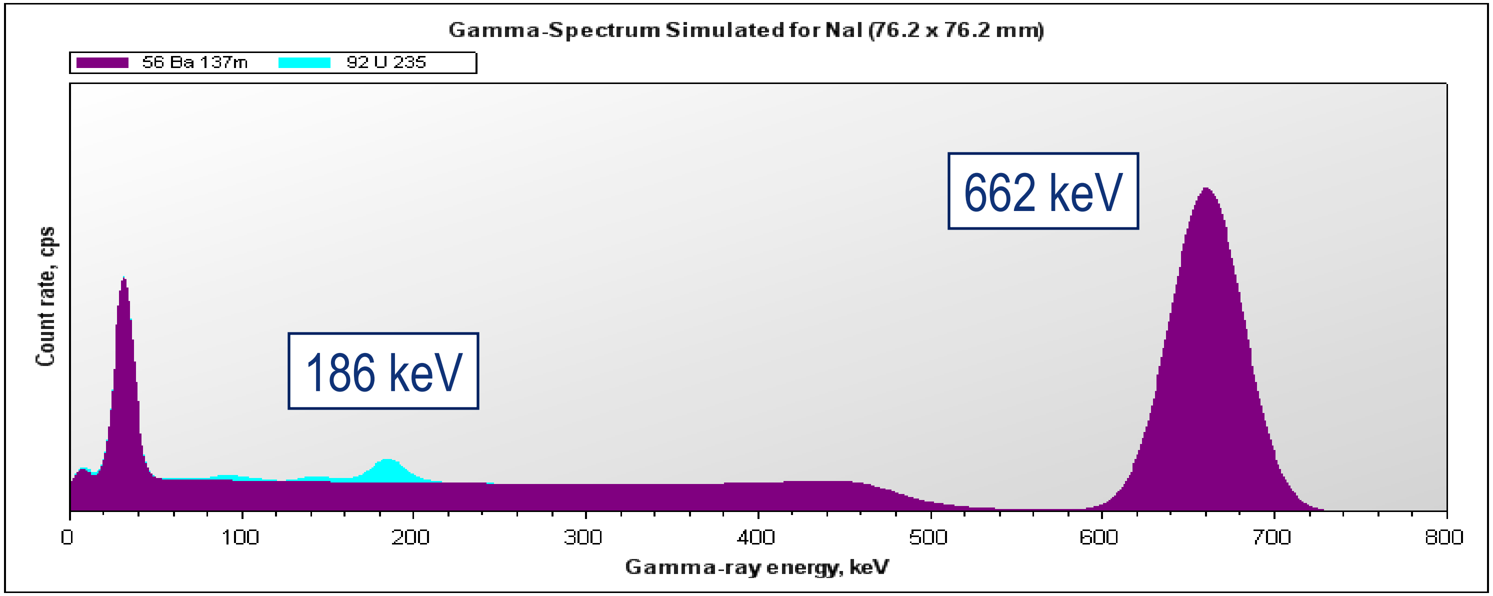
$E'_{back\_cobalt} = 210, 214$ keV

for great primary energies:

$$E'_{back\_max} \sim 511/2$$

peak always at 255 keV or less

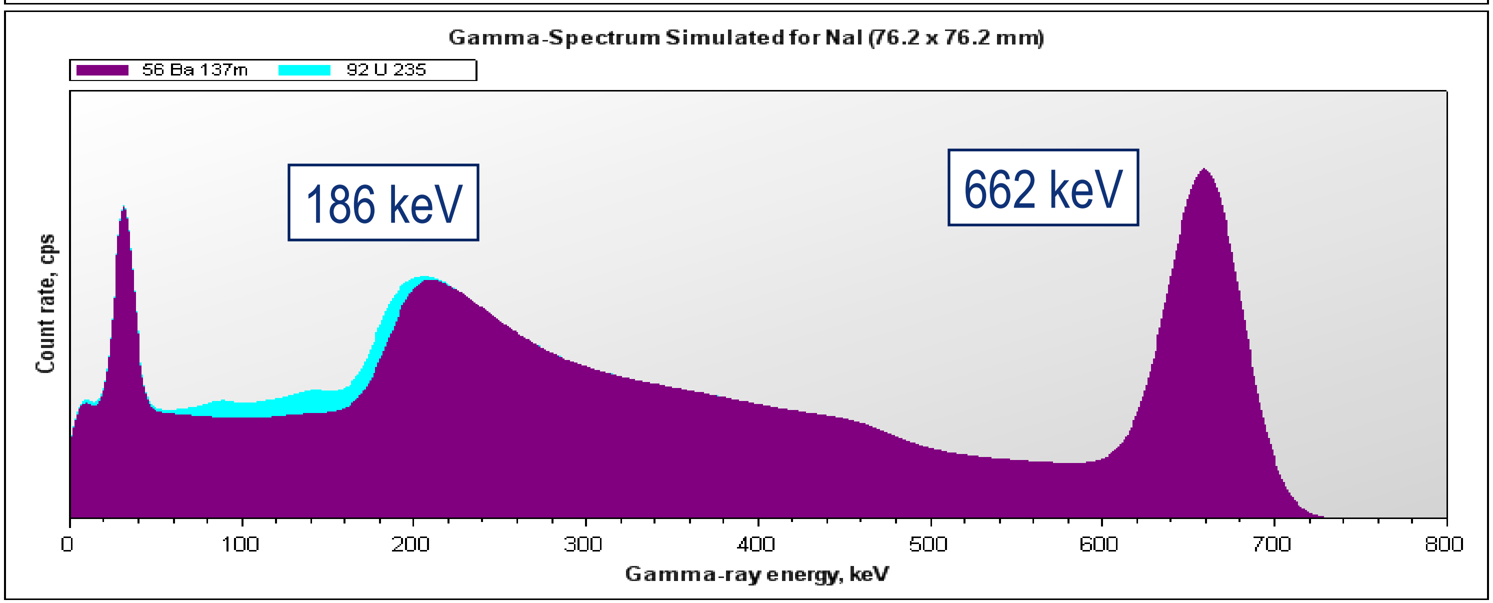
Cs 137 and HEU



Cs 137 + U 235

No backscattering contribution

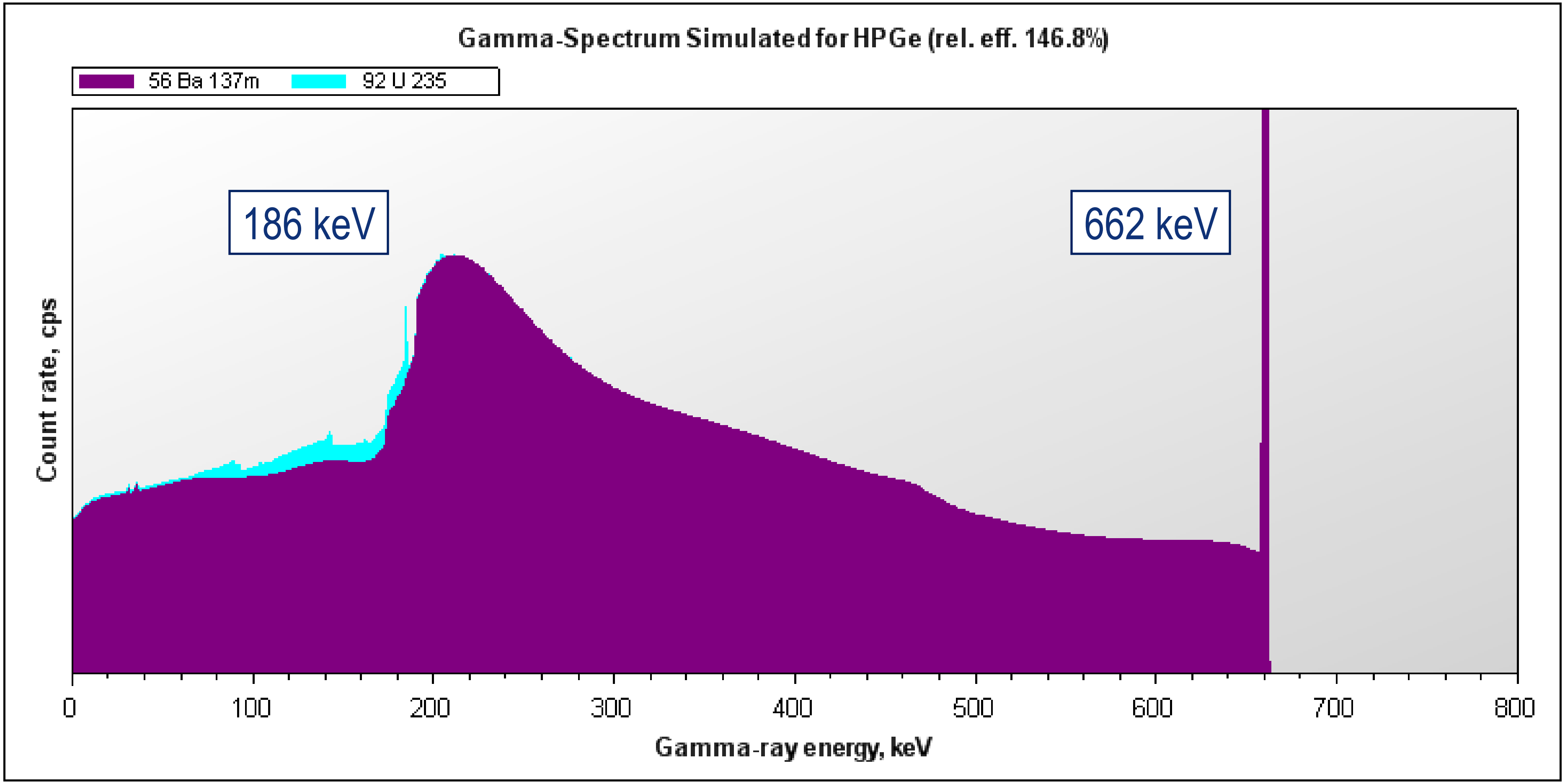
U 235 peak at 185,7 keV clearly visible



with backscatter peak

U 235 peak hidden

Cs 137 and HEU



with high backscattering interference also in HPGe spectrum

Preventing Masking

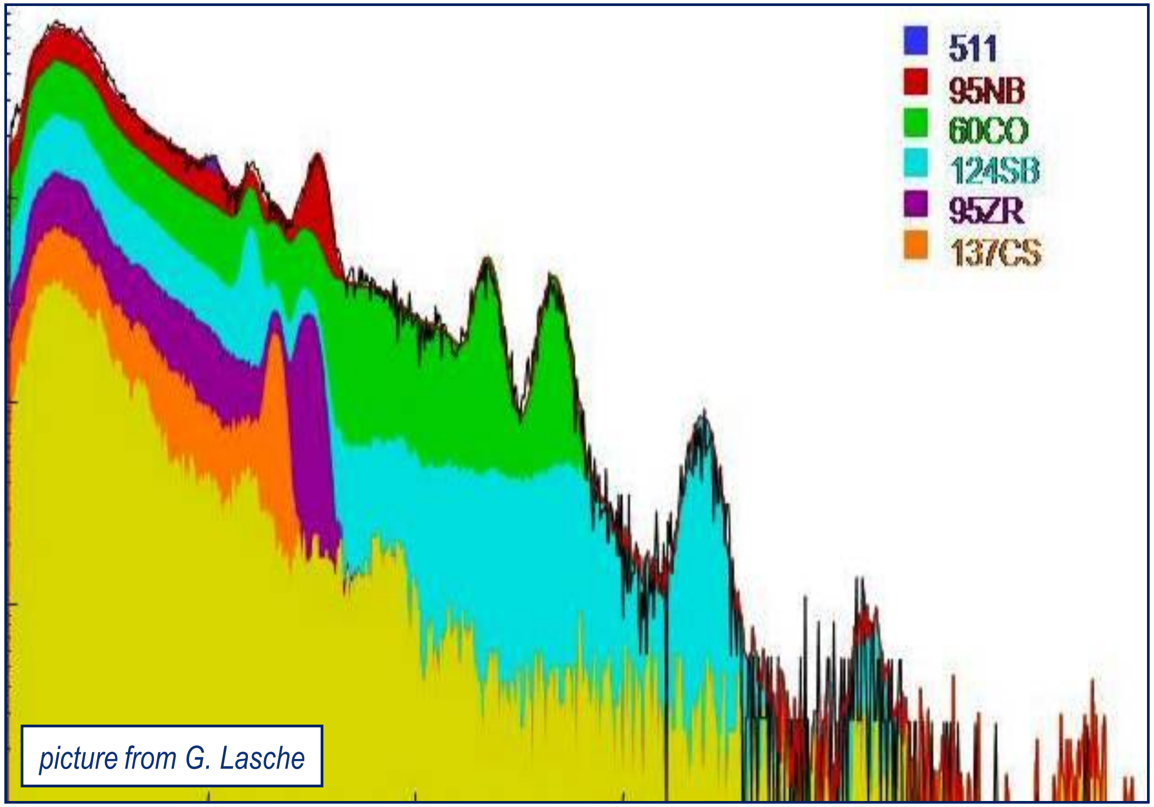
countermeasures:

- high resolution detectors (expensive)

- full spectrum analysis
  or template matching

- for neutron emitters:
  additional neutron detection

- to detect shielding
  or inhomogeneities:
  x-ray machines



picture from G. Lasche

Thank you for your Attention!

further recommended reading:

G. Knoll, *Radiation Detection and Measurement*

M.I. Reinhard et al., *Detection of Illicit Nuclear Materials Masked with other Gamma-Ray Emitters*

R.M. Keyser and T.R. Twomey, *Detector resolution required for accurate identification in common gamma-ray masking situations*

IAEA Nuclear Security Series No. 6, *Combating Illicit Trafficking in Nuclear and other Radioactive Material*